Review of Five and Time and Motion Studies Completed on Root Removal Treatments In the Nelson Forest Region

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ABSTRACT

Armillaria (*Armillaria ostoyae*) has been identified as a serious pathogen in southern interior forests of British Columbia. With both scientific and operational input, the Nelson Forest Region, Silviculture Section, has prepared a draft Standard Operating Procedure (SOP) for Armillaria control. Root removal at the time of harvest is one of the treatment options for Armillaria control recommended in the SOP. One aspect of particular interest to operational staff, is the relative productivity and costs of a root removal treatment. In the last decade, five trials (three stumping and two pushover falling) have been undertaken in this region, to evaluate productivity and costs. This report summarizes these "Time and Motion" trials, and makes recommendations for further study.

The Regional Valuation Section used information from these studies to calculate cost estimates for stumping and pushover falling treatments. They have also been collecting "tree to truck" figures for all pushover harvesting operations in the Nelson Forest Region since 1992. This information will help refine the cost estimates. Therefore, it is not necessary to complete more "Time and Motion" trials with the objectives of updating cost information for the appraisal system. Instead, future "Time and Motion" trials should be designed to answer specific operational questions. Clear objectives will facilitate selection of study methods. Reports should be more detailed in describing study objectives, methods, and site descriptions. Specific issues of interest include: the effects of different methods of stump management on the productivity of the operation; the effects of stumping and pushover falling on subsequent silvicultural treatments, and specifically, whether or not the disturbance from pushover falling replaces site preparation in some cases, and thus reduces the silvicultural cost.

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1.0 INTRODUCTION

Armillaria *(Armillaria ostoyae)* root disease has been identified as a serious pathogen in southern interior forests of British Columbia (Morrison et al. 1991). Over the past decade provincial and regional pathologists have completed considerable research on the biology of Armillaria, and have initiated preliminary research into some management strategies for controlling the spread of this disease. In the Nelson Forest Region, the control of Armillaria has become an important management issue. A recent survey of Douglas-fir plantations in the Arrow and Kootenay Lake Forest Districts found that many of these sites may not reach free growing status. Armillaria root disease was identified as a major contributor to this setback (Hopkins and Stewart 1992).

With both scientific and operational advice, several treatment options designed to reduce the spread of Armillaria have been outlined in a draft Standard Operating Procedure[1] (SOP) for the Nelson Region. Root removal at the time of harvest is one of the treatment options currently in the SOP for Armillaria control. The effectiveness of the treatment is being evaluated by a broad range of specialists. Some aspects of particular interest to operational staff, have been relative productivity and costs of the treatment and subsequent improvements in techniques. In the last ten years, several trials have been undertaken in the Nelson Region, to evaluate productivity and costs of different root removal treatments. This type of information is usually collected using Time and Motion studies.

2.0 OBJECTIVES

The objectives of this report are:

- to summarize the Time and Motion trials that have been completed on root removal treatments in the Nelson Forest Region,
- to determine if further time and motion information on root removal treatments is required, and if so,
- recommend standards for future studies.

3.0 TIME AND MOTION STUDIES

3.1 Definitions

Time and Motion studies can be used to monitor productivity of operations for a variety of objectives, including:

- time standards (targets) for planning, costing, and scheduling,

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[1]Silviculture Section. 1993. Draft Standard Operating Procedure for Armillaria Control. Nelson Forest Region. Nelson, B.C.

- time standards (targets) for planning, costing, and scheduling,
- productivity evaluation (Hodson 1992)

In the productivity evaluation of timber harvesting operations, shift level and detailed level methods are commonly used.

3.1.1 Shift level

Shift level studies provide an overview of average hourly production. It is based on an observer's or worker's records of hours worked and pieces handled during an entire operation (Olsen and Kellogg 1983). Shift level studies monitor machine usage or Productive Machine Hours (PMH). PMH is the in-shift time that the machine is doing what it is scheduled to do, such as skidding or pushover falling. Non-mechanical and mechanical delays are taken out of total time. A Servis recorder[2] is commonly mounted on a machine to measure when the machine is working or "in motion".

3.1.2 Detailed level

The detailed level study determines and monitors each activity a machine or person does during the hours worked. The two most common approaches for monitoring timber harvesting activities are **stop watch studies** and **work sampling**.

1. **Stop watch** method involves continuous timing to observe, measure and record the length of time required to perform an activity. Notations of distance traveled, pieces handled, and piece size are also documented.

2. **Work sampling** method consists of random or fixed interval observations to determine how much of the total work time has been spent in various states of activity or inactivity. Distance traveled, number of pieces, and piece size are collected with independent tallies (Conway 1982).

For both types of detailed time study, work performed by a machine or person, is divided into activities or **elements**. An element is a distinct part of an activity (i.e. hooking as part of skidding). It can be made up of one or more motions and/or machine activities selected for convenience of observation and timing.

3.2 Discussion

Shift level study is a gross time-study technique that is better suited to developing average cost figures for an operation than detailed studies, because they more accurately reflect total down time of an *entire* harvesting operation. In addition, data collection for a shift level study cost much less per study than for a detailed study. Therefore, information from *more* operations can be collected (Olsen and Kellogg 1983).

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[2] A Servis recorder is a devise that measures motion when mounted on a machine.

Detailed level studies are often used if the objectives of the study include trying to identify how productivity (by phase) of a new type of operation differs from a conventional operation, or how two machines doing the same function compare. The detailed level study is often used in conjunction with a shift level study and provides more information about a particular activity within an operation. Detailed studies can also help identify how an operation can be made more efficient. Regression equations to predict productivity under varying conditions can be developed from this data as well (Olsen and Kellogg 1983). The stop watch method of timing is used most often for monitoring harvesting activities. However, if an activity is moving very fast (i.e. falling) from one element to another, the work sample method is more appropriate (Conway 1982).

When completing a detailed level study, elements should be clearly defined before the study is started. Several types of elements are found in a time study:

- regular: occur in every cycle,
- irregular: do not occur in every cycle, but may occur at regular or irregular intervals,
- foreign: not a necessary part of work (delays) (Hodson 1992).

The Forest Engineering Research Institute of Canada has developed standard elements for Time and Motion studies (Appendix 1). With standard element descriptions, consistency is obtained in all time and motion studies. However, a certain amount of flexibility is required, especially for new operations. If unfamiliar with the operation, preliminary observations should be made to determine which elements to include. Open space should be left on the study form for the addition of unexpected events. Non-standard elements should be clearly described.

3.3 Cost determination

Once productivity information is collected with a shift level or detailed level (where all activities are monitored) study, cost per unit of production (i.e. $/m3) can be calculated for an operation. The ownership, operating and repair costs of the equipment, and labour costs are normally included in total cost per hour. The total cost per hour is multiplied by the productivity per hour to get a cost per unit of production. A standard source and method of calculation for equipment and labour rates should be used to permit comparisons between operations.

4.0 SUMMARY OF TIME AND MOTION STUDIES IN THE NELSON FOREST REGION

4.1 Overview of trials

The first experimental root removal treatment was completed in the Golden Forest District in 1983. This treatment involved removing stumps from the ground with a D-7 Cat after the harvesting operation was completed. The objectives of this study were to determine economic feasibility of stumping, and to assess site impacts. In 1988, Evans Products Ltd completed another trial in the Golden Forest District. In this trial a new treatment that

pushed entire trees over (pushover falling) as part of the harvesting operation was compared to post-harvest stump removal. The objectives of this study were to compare costs and site disturbance of the two treatments. In both trials, very rough shift level information was collected and costs for the operations were estimated. These two trials were completed during the developmental stages of root removal treatments. Since then, the efficiency of these treatments has been improved and they are being used operationally in the Nelson Forest Region. With expansion to operational use, the Nelson Forest Region Valuation Section required a cost estimate to use for calculating appraisal allowances for stumping and pushover falling.

Three detailed time and motion studies on root removal treatments have been completed in the Nelson Forest Region since 1989. These studies were commissioned by Don Norris (Regional Pathologist) to provide the Nelson Forest Region Valuation Section information with cost estimates. Descriptions of the sites and summaries of the studies are presented in Tables 1 and 2. Further detail on each trial follows.

Table 1. Site descriptions

Site	District	opening	treatment	biogeo	site series	timber type	stand density	ha.	slope	soil texture	season of harvest	year completed
Knappen Cr.	Boundary	82E048-37	stumping	ICHmk1	4	Pli.wFd (CwPw)	451*	50	10-40	SL.	fall	1989
Stewart Cr.	Boundary	82E009-48	pushover	ICHdw	1	LwFdPl (Sel lw)	?	8	10-30	L.	winter	1991
N. Slewiskin	Arrow	82K012-019	pushover	ICHmw 2	1	Fdl.w (PwCw)	592*	5.1	30	SL.	winter	1992

*merch only

Table 2

Site	Treatment	Objectives	Methods	Timing elements	Machines	Hours timed	Costing methods	Cost
Knappen Cr	stumping	"to remove stumps with a brushrake equipped cat227 excavator". "to develop more efficient techniques of stump removal and reduce costs of operation"	detailed timing	**Excavator:** •stacking slash •stump removal •tree removal •root raking •travel	Cat 227 excavator	1989- 8hours 1990- 9.5hours	total cost /# of hectares treated	Stumping only 1989-$1463/ ha 1990- $1213/ha
Stewart Cr	pushover	"to combat MPB and Armillaria by using a new process known as pushover falling"	detailed timing & shift level by observation	**Skidder:** •skidding and choking •road work •landing work **Excavator:** •falling •site prep •stump piling •landing function •travel **Buckerman:** •landing •other	JD648D Grapple skidder JD790D Excavator	**Skidder:** 62 hours 49 min **Excavator:** 65 hours 48min **Buckerman:** 66 hours 17min (the above figures are total time, % detailed timed unavailable)	Total hours of operation X hourly cost figures (BC hydro rates and contractor rate)	Tree to truck BC hyro rates $4840/ ha $16.2/ m3 Contractor rates $5618/ ha $18.4/ m3
N. Selewaskin Cr	pushover	"to determine the time and costs involved for each phase in a pushover logging operation"	detailed timing & shift level by observation	**Skidder** •walk, drag •choke, unchoke •piece count **Excavator:** •fall, bunch •falling broken down to dig, push, drop •trail •mormerch •walk •fuel, break, other **Loader** •logs •debris •loading •breaks, other **Buckerman:** •bucking •sharpen, fuel •break	1 Clark ranger and 1 International 510 line Skidder Cat 225/235 Excavator Cat 950 loader	**Skidders:** 120 hours, 39 hours **Excavator:** 97.8 hours **Loader:**130 hours **Buckerman:** 173 hours 36min (the above is total time, % detailed timed is unavailable)	Total hours of operation for each phase X hourly rates (BC hyro rates)	Tree to truck $7342/ ha $19.41/ m3

4.2 Knappen Creek

In 1989 and 1990, stumping operations using a Cat 227 excavator, were completed on portions of a 51.1 hectare block near Grand Forks, B.C.(Nazaroff 1989, 1990). The excavator was detail timed (stop watch method) on 3 one-half ha plots within the block in 1989, and 5 more one-half ha plots in 1990. Elements used during the timing included: stacking slash, stump removal, tree removal, root raking, and traveling (Figures 1 and 2).

4.2.1 Study results

There was an average of 1070 stumps/ha in the three plots timed in 1989, which took an average of 20 seconds/stump to remove. Nazaroff (1989) recommended that it would be more efficient to pile and burn slash before stumping, as it slowed the operation down considerably (20% of the excavator's time was spent stacking slash). Modifications on the design of the brush rake attachment were suggested as well

There was an average of 451 stumps/ha. in the five plots timed in 1990. The average time to remove a stump was broken down by diameter class:

Diameter class	Seconds to remove stump (average)
5-15 cm	13
15-25 cm	20
25-35 cm	33.5

for an overall average of 1.09 seconds per cm of diameter. The higher proportion of time spent stumping and the cheaper cost ($250/ha less) in the 1990 operation was attributed to fewer stumps, fewer residual trees, and that the slash was piled before stumping. However, similar proportions of time were spent stacking slash in both operations (Figures 1 and 2). It was noted that large healthy stumps could take three to four times longer to pull out than infected stumps.

4.2.2 Discussion

Observations were made about how the efficiency of the operation could be improved. In this respect the trial met its stated objectives. However, more information on site characteristics (the site information in Table 1 was collected from the District), how and why the elements were chosen, how the operation was completed, and how the total cost figures ($/ha) were determined, would have made the reports more comprehensive.

The results of this study are used by the Valuation Section (Nelson Forest Region) as a basis for cost estimates for root removal treatments to add onto the appraisal allowance. The total stumping time is estimated based on merchantable stand density and stem diameters (1 second per centimeter (by 5cm diameter class) for stems under 35cm diameter, and 2 seconds per centimeter diameter for stems greater than 35 cm). The total stumping time figure is multiplied by $148/hour (or the current hourly figure for an

excavator) for a cost /ha figure, which becomes part of the cost estimate for the appraisal allowance[3].

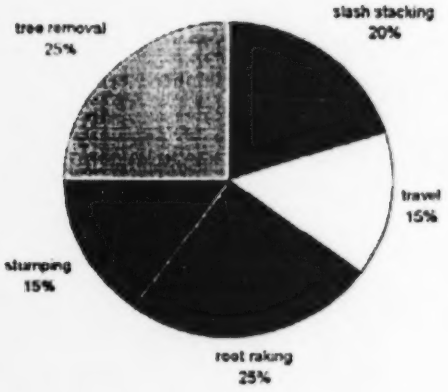

Figure 1. Distribution of total time -1989 operation at Knappen Creek.

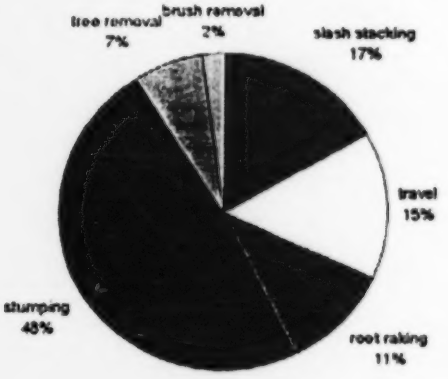

Figure 2. Distribution of total time -1990 operation at Knappen Creek.

[3] This method is also used for calculating cost estimates for pushover harvesting operations. However, the Regional Pathologist recommended that the figure be multiplied by .75 (based on experience and "gut feel") to more accurately reflect the cost of pushover harvesting operations versus stumping.

4.3 Stewart Creek

In 1991, the first Time and Motion study of a pushover falling operation was completed in the ICHdw near Grand Forks, B.C.(Toews and Nazaroff 1991). Detailed timing (stop watch method) was completed on the pushover falling, skidding, bucking, and loading phases. Several elements in each phase were timed with the exception of delays (Table 2). A total of 8.1 hectares were treated. Approximately 30% of the operation was detail timed. For each of the phases, pie charts of the elements timed were presented (Figures 3 to 6).

4.3.1 Study results

The whole tree was skidded to the landing where the stumps were bucked off. Bucking was more difficult than normal, as the root masses were cut off at the landing. It was also noted that several of the stems were being bucked off below ground level, possibly increasing utilization. Both B.C. Hydro rates and the contractors rates were used to calculate costs (Table 2). Production rate (m3/hour) by phase was not measured. Cost per m3 was calculated using total scaled volume.

4.3.2 Discussion

The report does not outline the specific objectives of the Time and Motion study. It is therefore difficult to assess whether the study objectives were met. Data presentation through pie charts showed the distribution of timed elements for each function and was clear. In reference to cost figures, the contractor rate based costs were $2/m3 higher than the B.C. Hydro based costs. This difference illustrates the importance of using a standard method for calculating operation costs.

Additional information on the site and how each machine was being used would have been useful. Further information on piece counts by phase would have permitted production per phase calculations.

Some of the functions could have had more elements for detailed timing. For example, if the pushover falling element was subdivided, the function would have been described more clearly. Delays were not explicitly broken out and defined for any of the elements. In the case of the buckerman's function, where only two elements were timed; "landing work", and "other", it is not clear what *tasks* the buckerman was doing on the landing. It is expected that the bucking functions would be different for pushover versus conventional falling, because in the latter case the trees are not skidded to the landing with roots attached. Further, it is usually not necessary to detail time elements not influenced by the pushover falling,or whole tree skidding and bucking, such as the time spent by the skidder "towing the truck" (Figure 3).

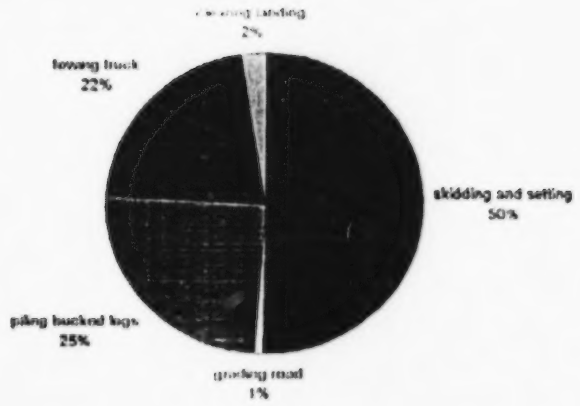

Figure 3.Skidding elements at Stewart Creek

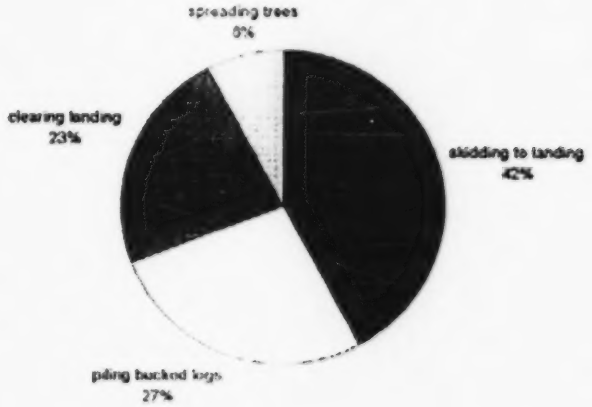

Figure 4. Distribution of skidding function elements only at Stewart Creek.

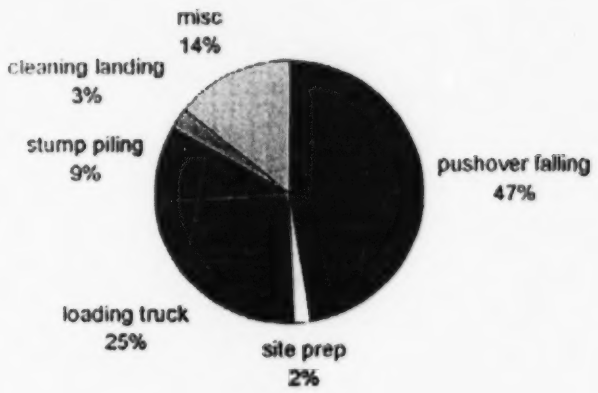

Figure 5. Excavator Elements at Stewart Creek.

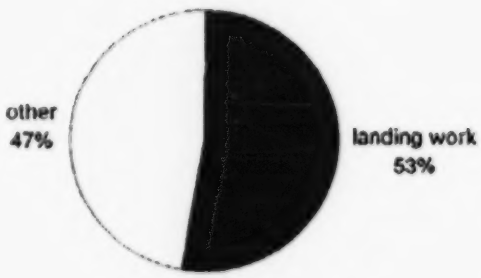

Figure 6. Bucking Elements at Stewart Creek

4.4 North Slewiskin Creek

In 1992, another pushover falling operation was detailed timed in the ICHmw2 near Nakusp, B.C. (Walsh 1993). Five hectares on a 10.6 hectare block were pushover felled. Whole trees (stumps and roots attached) were skidded to the landing for processing. Detailed timing was completed on the excavator, skidding, bucking, and loading functions to generate a tree to truck rate. The activity of pushover falling was also divided into elements for detailed timing. See Table 2 for further description of the elements used for each function.

4.4.1 Study results

Using B.C. Hydro equipment rates, a tree to truck rate of $19.41 /m3 was generated for the operation. Falling was the largest portion of this cost (Figure 7).

The excavator push felled an average of 112 trees/hour with a range of 42 to 226. Walsh (1993) noted that this was highly dependent on size of the trees and stand density. About one half of the trees felled were unmerchantable. Falling time per tree was determined to be 1.2 seconds per cm of diameter. The pushover falling activity within the excavator's functions (Figure 8) was broken down further (Figure 9). This detail can be useful for determining where a machine is spending its time within one of its functions. The analyst for this study indicated that it was difficult to measure the falling elements because the machine was moving too fast. This is a good example of where a work sampling technique would be more appropriate than the stop watch technique.

The average cycle time for the skidder was 16.5 minutes with an average production of 10 pieces per turn. Average skidding distance was not recorded. The loader had difficulty keeping up with the skidders because it had to spend more time clearing the extra debris from the stumps and root masses in the landing. An extra buckerman was also required to keep up with the skidders, as additional time was required to cut off the root masses. More time was spent sharpening saws because of the dirt on the tree at the below ground level.

4.4.2 Discussion

This study was detailed and comprehensive. There was good detail on the site characteristics, as well as how people and machines were organized to do the harvesting. The elements used in timing each phase were closer to the conventions used by the Forest Engineering Research Institute of Canada. However, if new elements are going to be used (which is often the case in new operations like pushover falling), clear definitions of when it starts and ends are essential for the reader to understand the operation and to keep subsequent studies consistent.

The study met its stated objectives of determining the time and costs for each phase of a pushover logging operation. There were some observations made about how different phases were affected by the whole tree harvesting. However, more discussion and interpretation of how the pushover operation might compare to a conventional operation would have been useful. For example, percent of cost by phase could have been presented

for an average conventional operation to compare with the numbers presented in Figure 7 for pushover falling

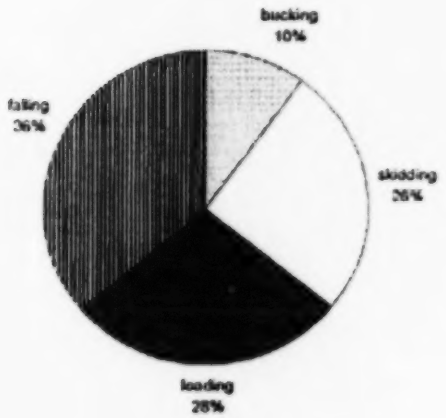

Figure 7 Percent of total cost by phase at North Slewiskin Creek.

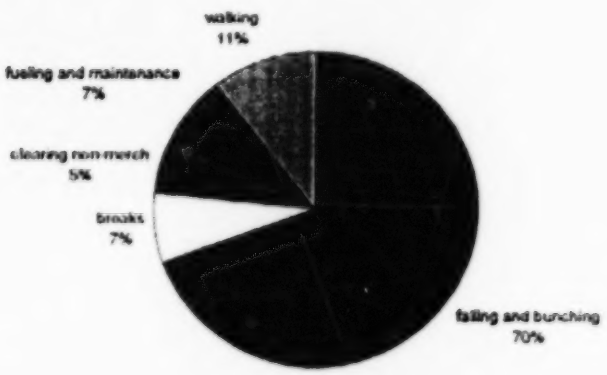

Figure 8 Excavator elements at North Slewiskin Creek

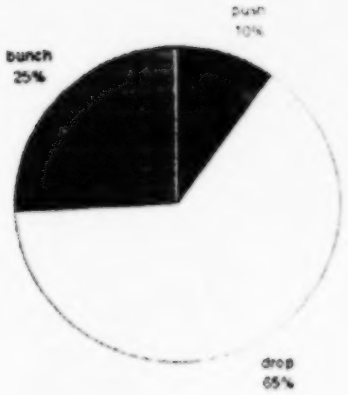

Figure 9. Pushover falling elements at North Slewiskin Creek

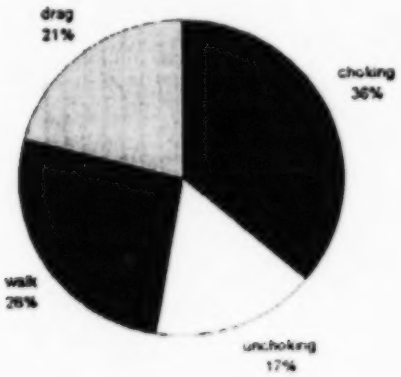

Figure 10. Skidding elements at North Slewiskin Creek

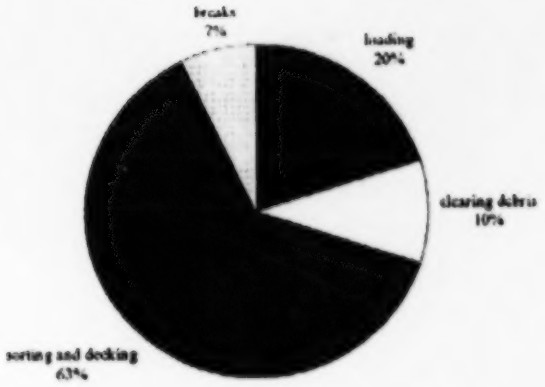

Figure 11. Loading elements at North Slewiskin Creek.

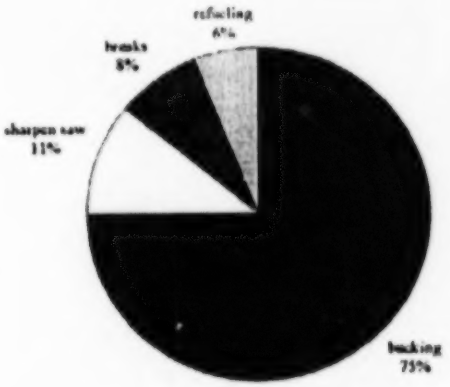

Figure 12. Bucking elements at North Slewiskin Creek.

5.0 SUMMARY AND RECOMMENDATIONS

The studies completed to date should be classified as investigative and exploratory in nature. In general, the study objectives were similar, namely to collect productivity and cost information on two Armillaria treatment options: stumping and pushover falling. While the purpose or use of this information was not specific in the reports, the results of the Knappin creek stumping trial provided the Valuation Section with a method of calculating a gross cost estimate to use in stumpage calculations for both treatments.

It is not necessary to complete more Time and Motion studies with the objectives of updating cost information for the appraisal system. The Valuation Section in the Nelson Forest Region collects tree to truck cost figures (rough shift level) for all types of harvesting operations. In 1992 they began to collect tree to truck figures for pushover falling operations separate from other types of operations. They currently have shift level cost figures for seven pushover operations (about 15% higher costs than for a conventional skidder operation). While the Valuation Section continues to collect this rough shift level information for updating the cost estimates, future Time and Motion studies commissioned by the Regional Silviculture Section should be designed to answer specific operational questions. Specific issues of interest include:

- the effects of different methods of stump management on the productivity of pushover falling, skidding, and bucking phase,
- which phase or phases contribute to differences in productivity of pushover falling versus conventional operations,
- the effects of stumping and pushover falling on subsequent silvicultural regimes. Specifically, does the disturbance from pushover falling replace site preparation in some cases, and thus reduce the silvicultural cost?[4]
- productivity and other implications of pushover falling in partial cut prescriptions.

Future Time and Motion studies need clear objectives. Clear objectives will facilitate selection of the study methods (whether a shift level and/or detailed study is required, and which elements to use). Reports should have more detailed site descriptions which include pre-treatment measures of stand density of merchantable and nonmerchantable stems (Appendix 2). By being more detailed in study objectives, methods, and site descriptions, more in-depth interpretations of the data and observations can be made.

5.1 Recommendations

- Working plans for further studies outlining objectives and subsequent methods should be prepared and reviewed prior to study implementation.

[4] This issue is currently being partially addressed through a research initiative of the Forest Sciences section in the Nelson Forest Region.

- stand density has been identified as a factor that influences productivity of stumping and pushover falling. In future studies, merchantable and unmerchantable stems need to be included in pre treatment measures,

- to ensure future studies are comparable, the list of standard elements presented in Appendix I should be used,

- new elements should be clearly defined,

- the most current B.C. Hyro 'all found'[5] equipment rates should be used as a standard in cost determination.

[5]Includes all costs including labour at union rates plus benefits.

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7.0 APPENDIX 1

Examples of standard[6] F.E.R.I.C. detailed level elements:

FALLING:

Manual falling[7]
move
cut
wedge
limb/buck
cut unmerch
sharpen saw
delay

Feller buncher
move to cut
cut
move to bunch
travel
brush
delay

Pushover falling[9]
Move (excavator travelling to position)
push (excavator pushing tree over with loading heel)
shake (excavator picking up tree at root collar with grapple and shaking dirt off roots)
grub (for residual roots)
brush (includes removing unmerch stems)
decking (for skidder)
delay

SKIDDING AND YARDING:

Skidding[8]
travel empty
position
hook
winch
travel loaded
unhook
delay

Decking at landing (separate function for skidder)
pile
clean
delay

Yarding
outhaul
hook
inhaul
unhook
delay

[6]Flexibility is always required, especially for new functions or equipment.
[7]Other descriptions and tallies that are added include: dbh, species, and # of trees cut
[8]Other descriptions and tallies that are added include: skidding or yarding distance, #of pieces per turn, and diameter
[9]Eric Philips, Researcher, F.E.R.I.C., Vancouver, B.C., personal communication.

Examples of standard F.E.R.I.C shift level[10] elements:

Total Machine Time (normal shift length plus overtime)	**Productive Machine Time** (includes delays< 10mins)
	Repair (includes modifications and improvements to equipment)
	Service (fueling, lubrication, etc.)
	Delays (>10mins) (non-productive operating time, personal breaks etc.)

[10]Adapted from (Heidersdorf and Folkema 1976)

8.0 APPENDIX 2

Recommended minimum site information[1] to be included in reports for pushover Time and Motion studies:

General:
District
opening if applicable
biogeoclimatic subzone and site series
slope
soil texture
coarse frag content

Pre-treatment:
stand density (# of stems/ha)
stand structure (diameter and height classes of merchantable and unmerchantable stems)
brush, slash, snow, etc. levels, or any other site factor that may influence productivity

Post-treatment:
site disturbance survey, etc.

[1] Flexibility is required as several measures will depend on study objectives.